



Heat Sink Design Considerations

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Outline

- Introduction
- Temperature budget and power dissipation
- Physical design requirements
- Design analysis and modeling techniques
- Thermal interface materials
- Heat sink test methodology
- Summary
- Future requirements



Power has increased in 5 years

- **Power = $N \cdot C \cdot V^2 \cdot f$**
- **Number of transistors has increased**
 - » 5 million --> 22 million
- **Gate length has been reduced**
 - » Gate oxide thickness has been reduced
 - » 0.35 μm ---> 0.18 μm
- **Voltage has been reduced**
 - » 3.3V ---> 1.75V
- **Frequency increase of ~10x**
 - » 100MHz ---> 1000MHz
- **Net increase in power of ~ 4-6X over five years**



Temperature impacts performance and reliability



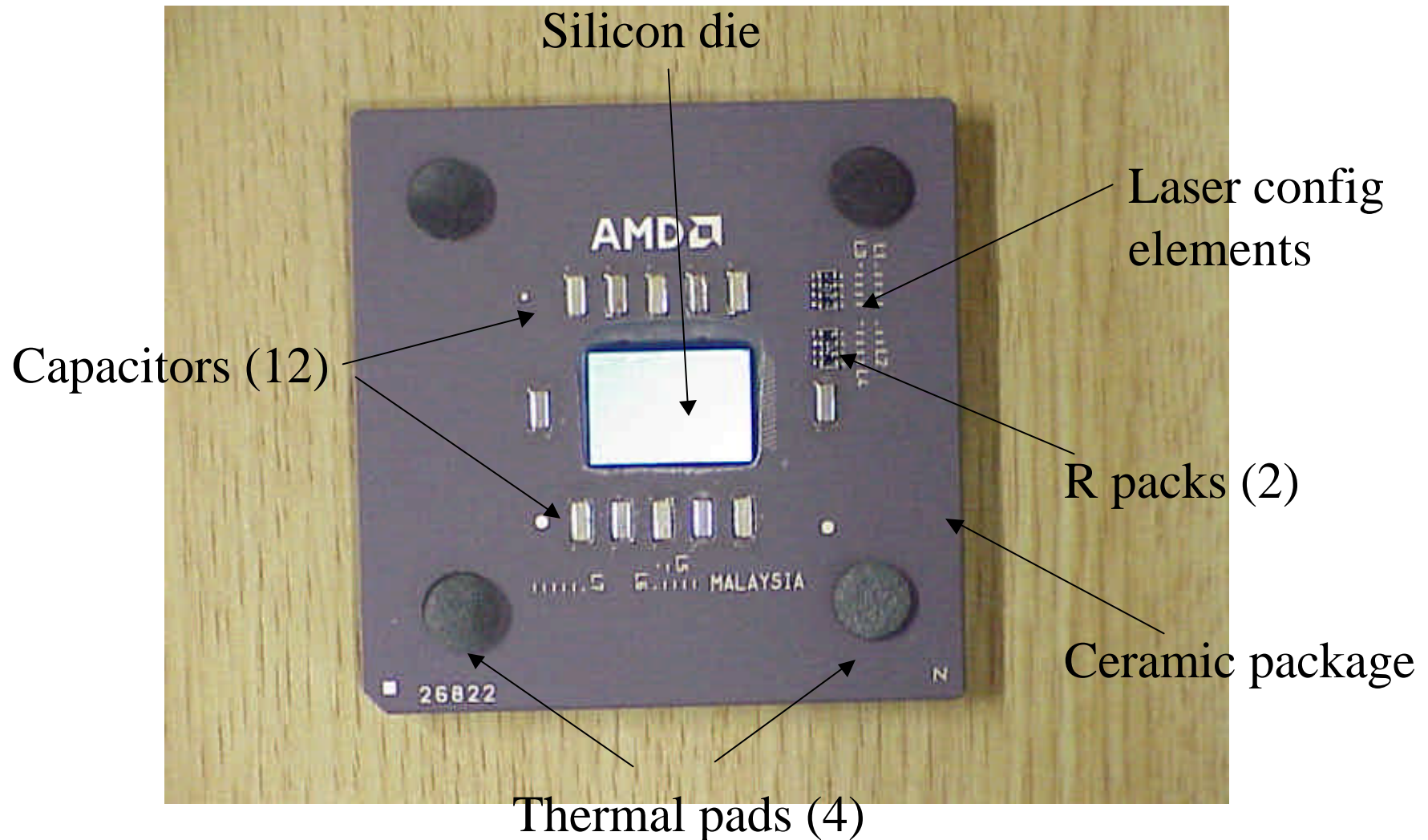
- **Performance of processor governed by**
 - ✍ architecture & circuit implementation
 - ✍ process technology
 - ✍ voltage
 - ✍ temperature
 - ✍ frequency
- **Reliability**
 - ✍ circuit implementation
 - ✍ process technology
 - ✍ temperature



Product Definition and Requirements



AMD Athlon™ and AMD Duron™ PGA 462 Processor

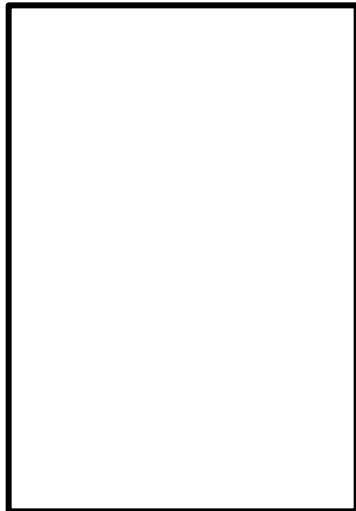




AMD Processor Family - Die Sizes



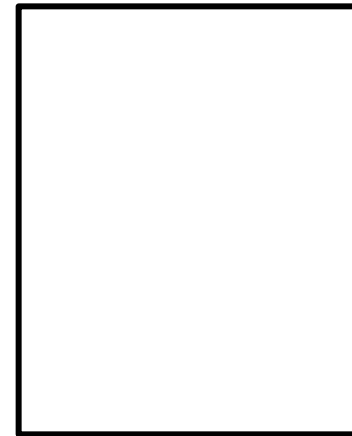
9.104 / 9.114



13.156 / 13.216

AMD Athlon™
256K
119.77mm²

8.944



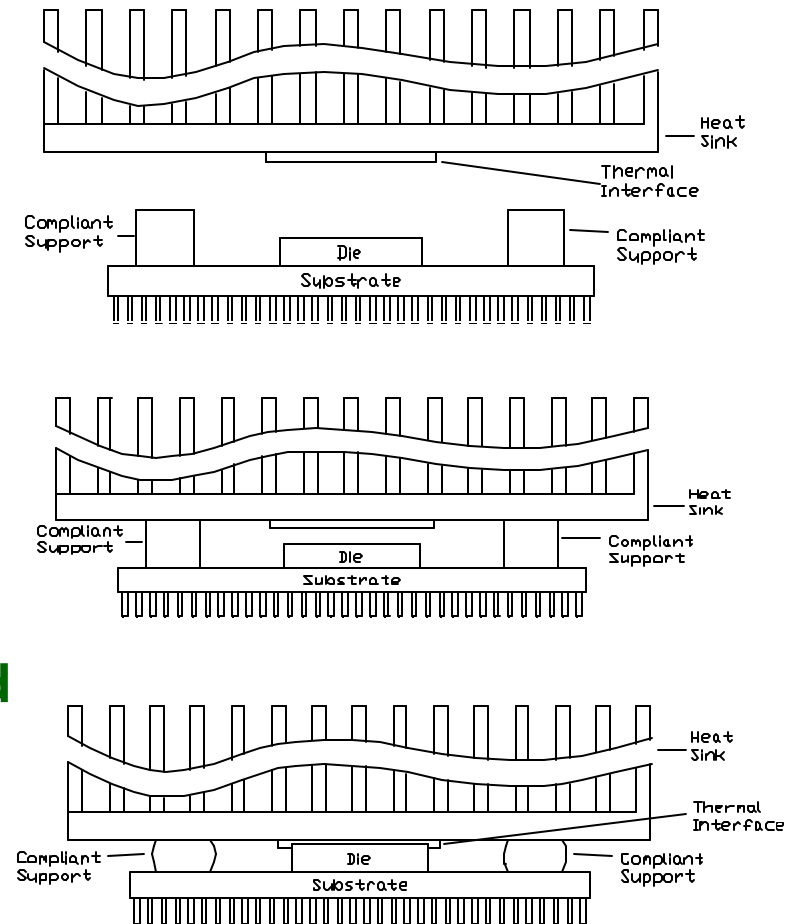
11.149

AMD Duron™
64K
99.72mm²



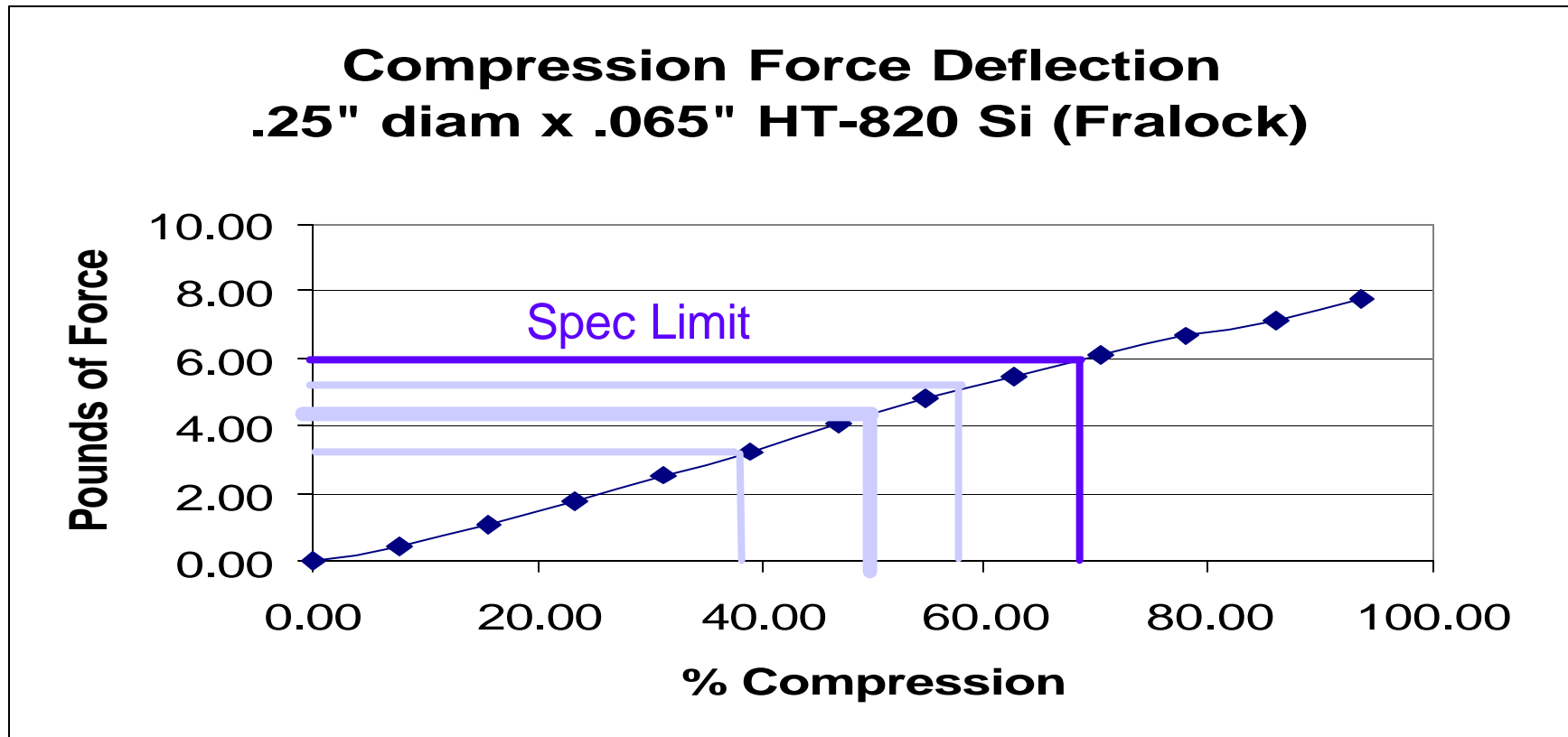
Effect of Compliant Thermal Pads

- Heat sink and package prior to installation
- Heat sink makes contact with pads and planarizes the two mating surfaces prior to clipping
 - ✂ eliminates heat sink rocking on die edge
 - ✂ NOTE: Heat sink does not contact die without clip!!!!!!
- With clip installed, pads compress and allow heat sink interface material to contact die
 - ✂ stabilizes heat sink on die for shipment





Reaction Load of Thermal Pads

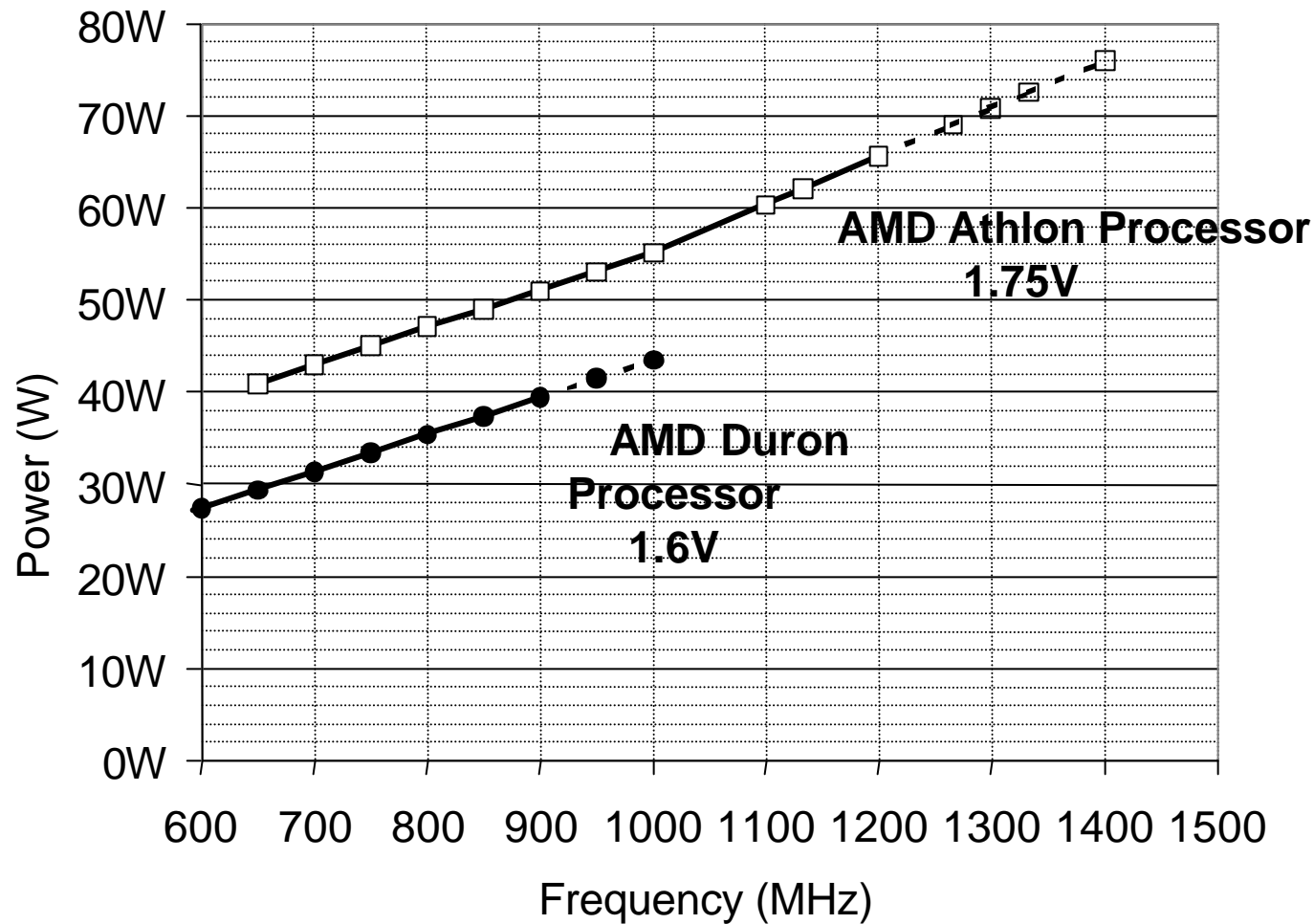




Power and Temperature Requirements



AMD Athlon™ and AMD Duron™ Processor Power





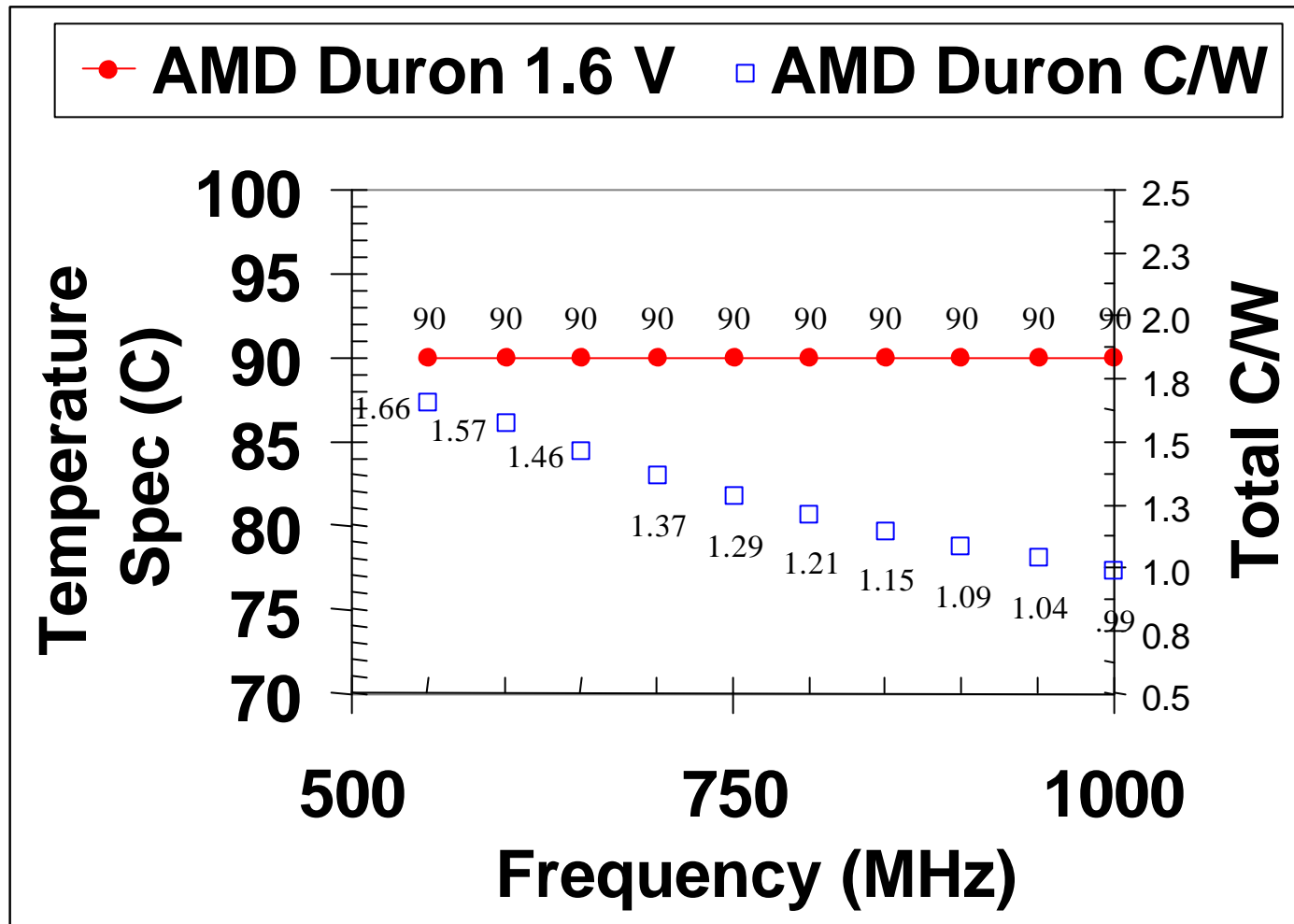
Temperature Budget for AMD Athlon™ and AMD Duron™ Processors



• Processor:	AMD Athlon	AMD Duron
• Max die temperature:	90 or 95 °C	90 °C
• Max external ambient:	35 °C	35 °C
• Air temperature rise:	7 °C	12 °C
• Local CPU ambient:	42 °C	47 °C
• Temperature budget:	48 or 53 °C	43 °C

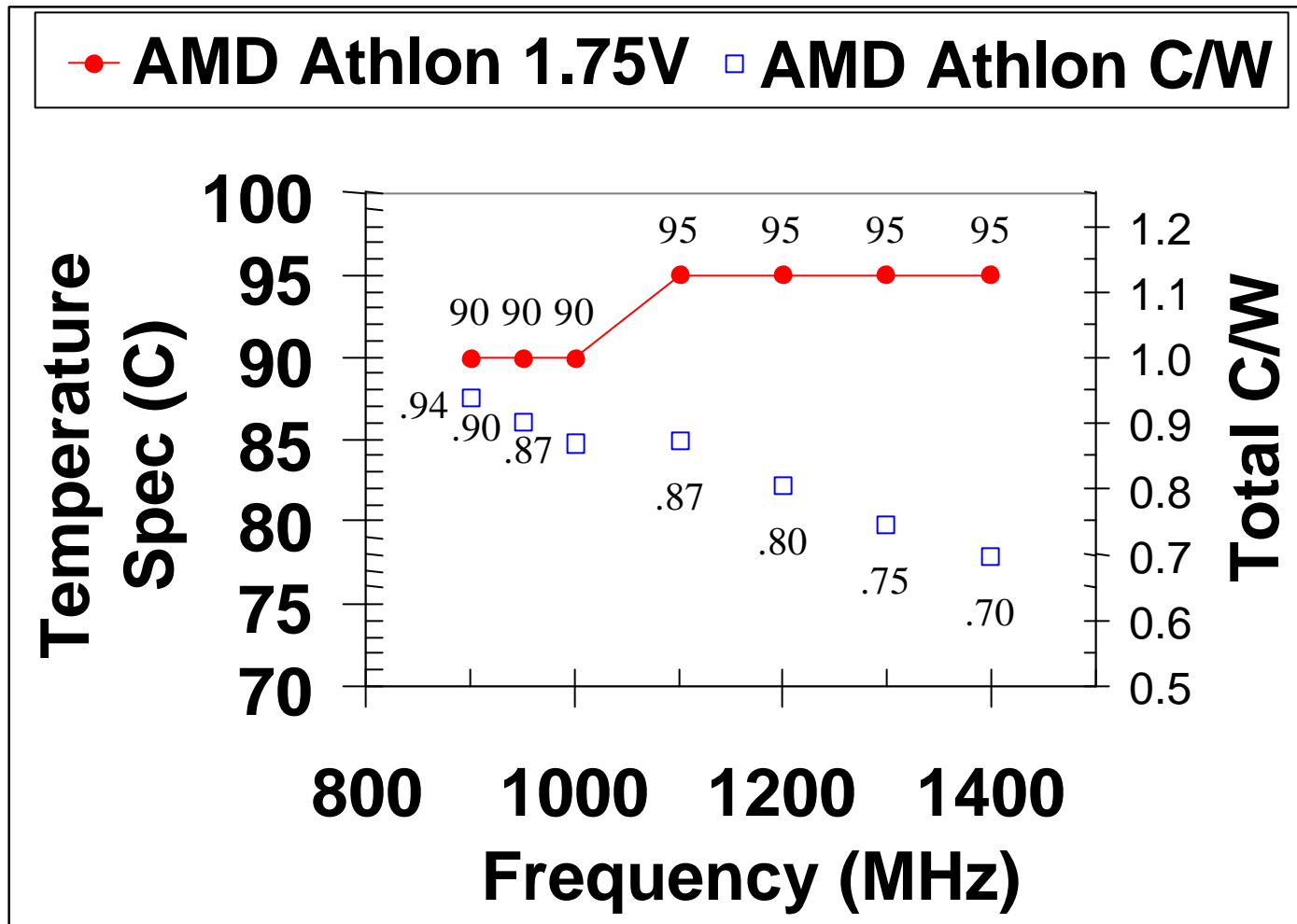


AMD Duron™ Processor Thermal Resistance Requirements





AMD Athlon™ Processor Thermal Resistance Requirements

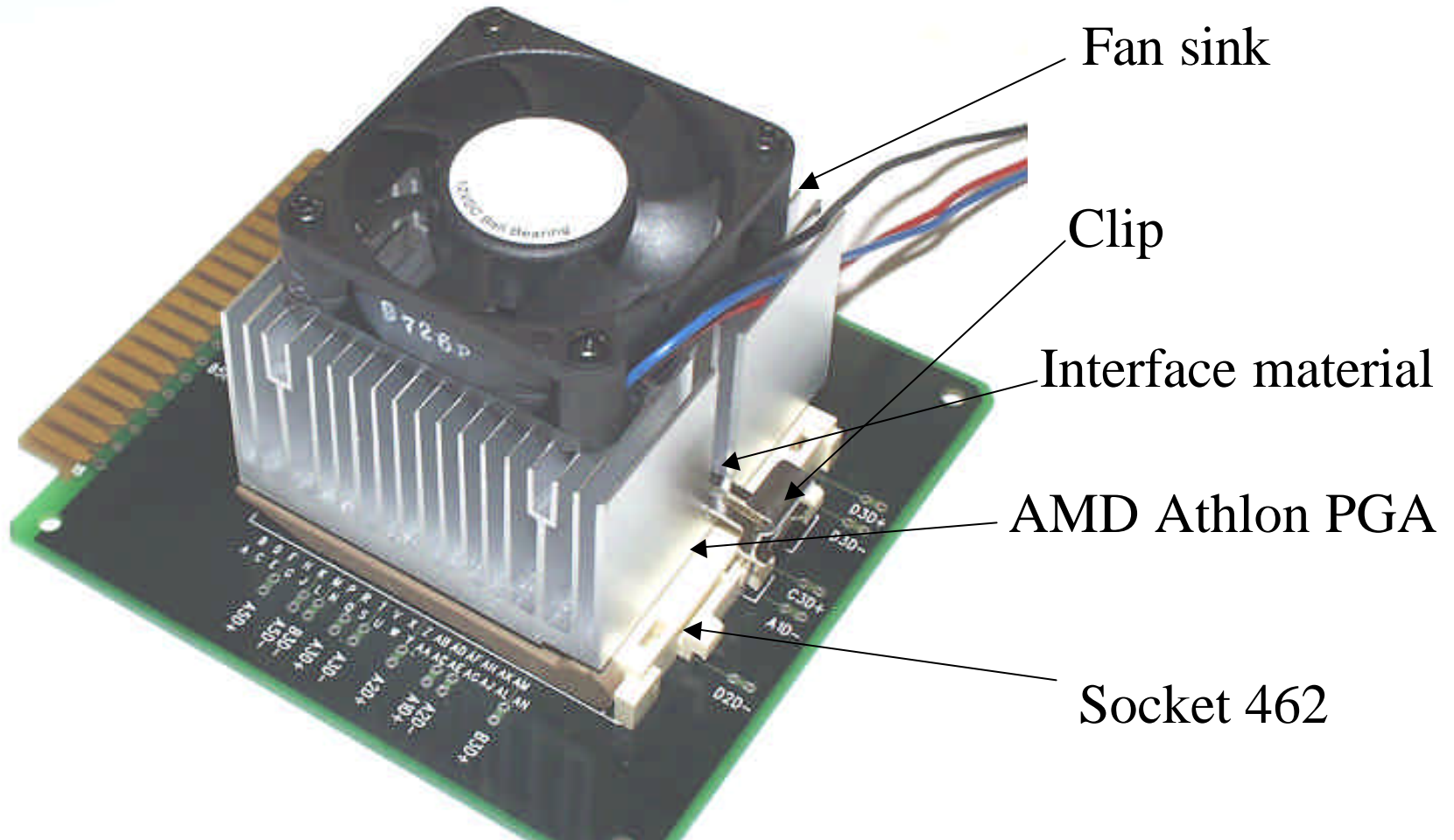




Heat Sink Reference Design Development

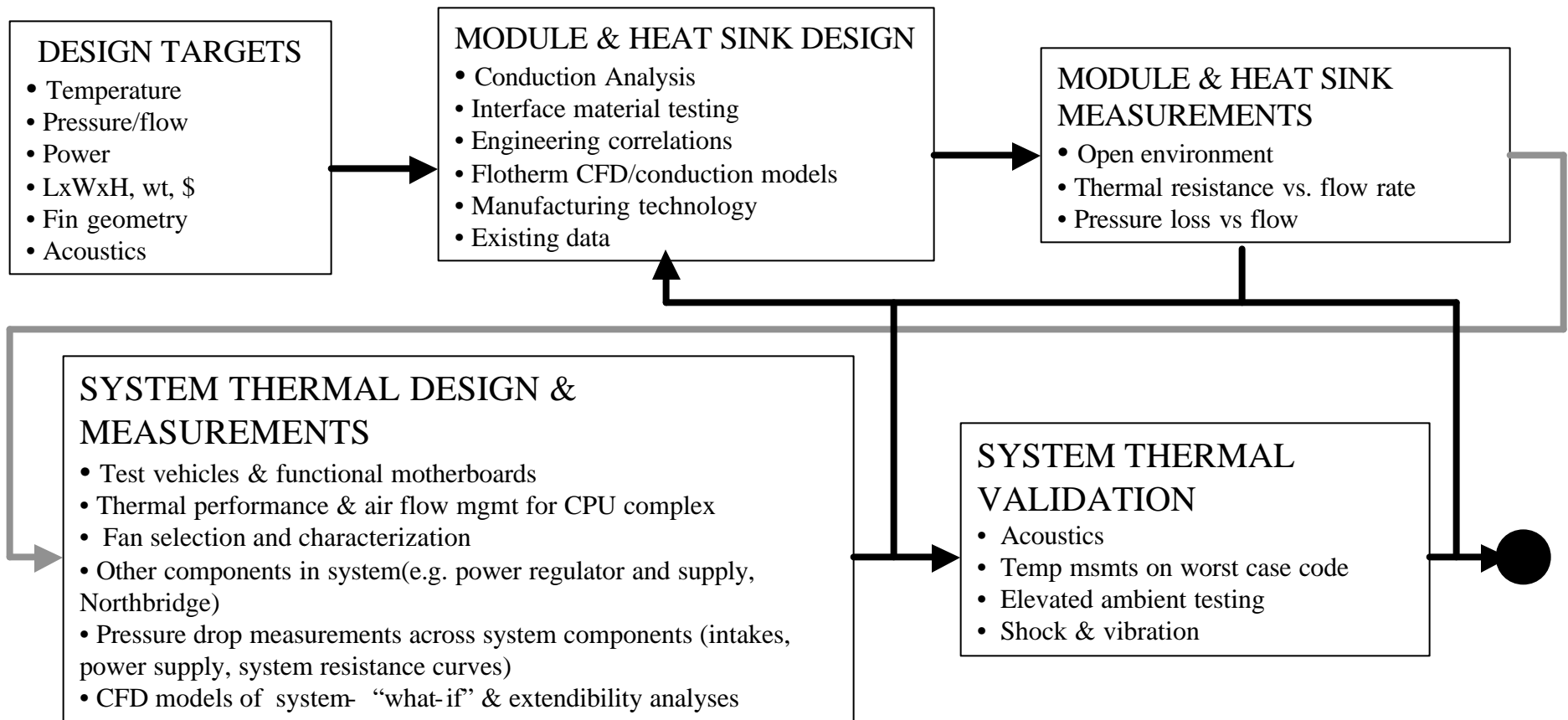


AMD Athlon™ PGA Processor Assembly





Thermal Design Flowchart



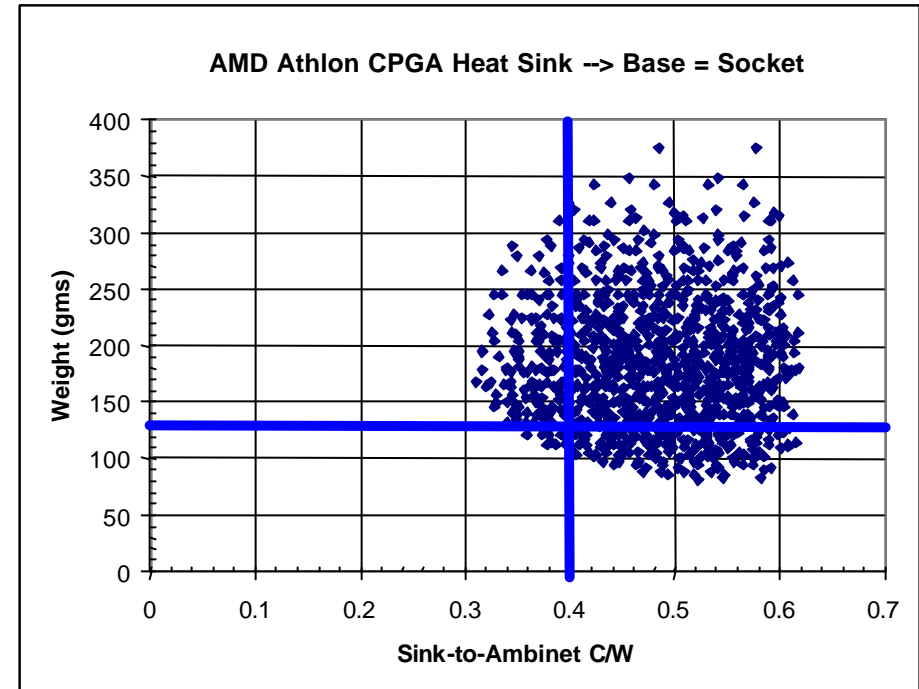
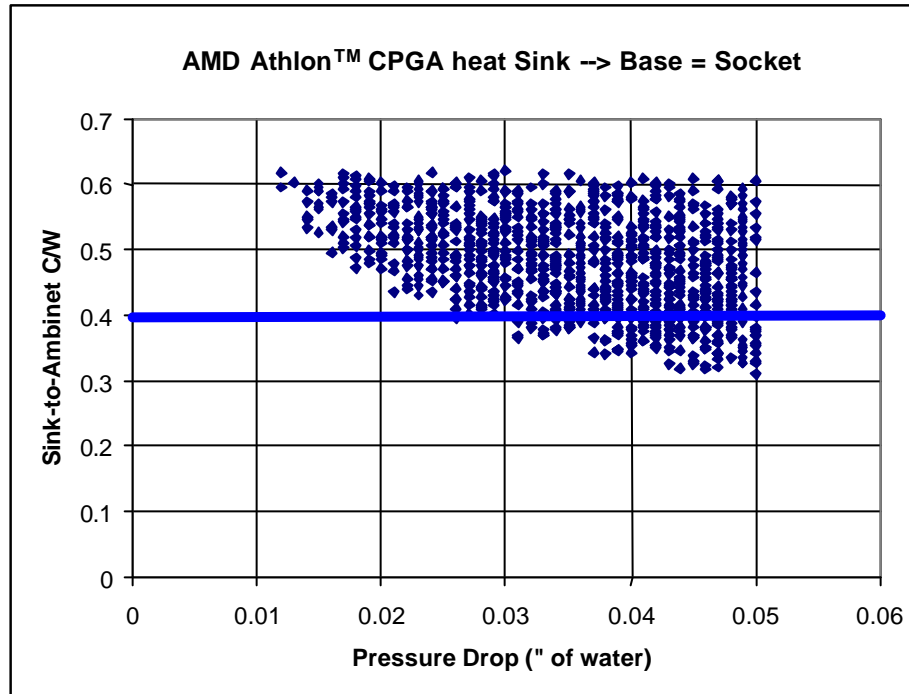


AMD Athlon™ PGA Fan Sink Design Targets

Symbol	Description	Min	Max	Notes
L	Length of Heatsink	60mm		Measurements are for the entire assembly including attached fan.
W	Width of Heatsink	60mm	80mm	
H	Height of Heatsink		60mm	
θ_{SA} Target	Sink-to-ambient thermal resistance:			
	For 48W processor		0.61°C/W	
	For 55W processor		0.44°C/W	
	For 70W processor		0.34°C/W	
θ_{JS} Target	Interface material thermal resistance:			Based upon core area
	For 48W processor		0.39°C/W	
	For 55W processor		0.44°C/W	
	For 70W processor		0.34°C/W	
CFM	Fan airflow	16cfm		Minimum 16cfm airflow
m_{HS} F_{clip}	Mass of heatsink Clip Force	12 lbs.	300g 24 lbs.	Typical F: 14 lbs. ? F ? 18 lbs. Nominal F = 16 lbs.
T_A	Inside the box local ambient temperature		42°C	

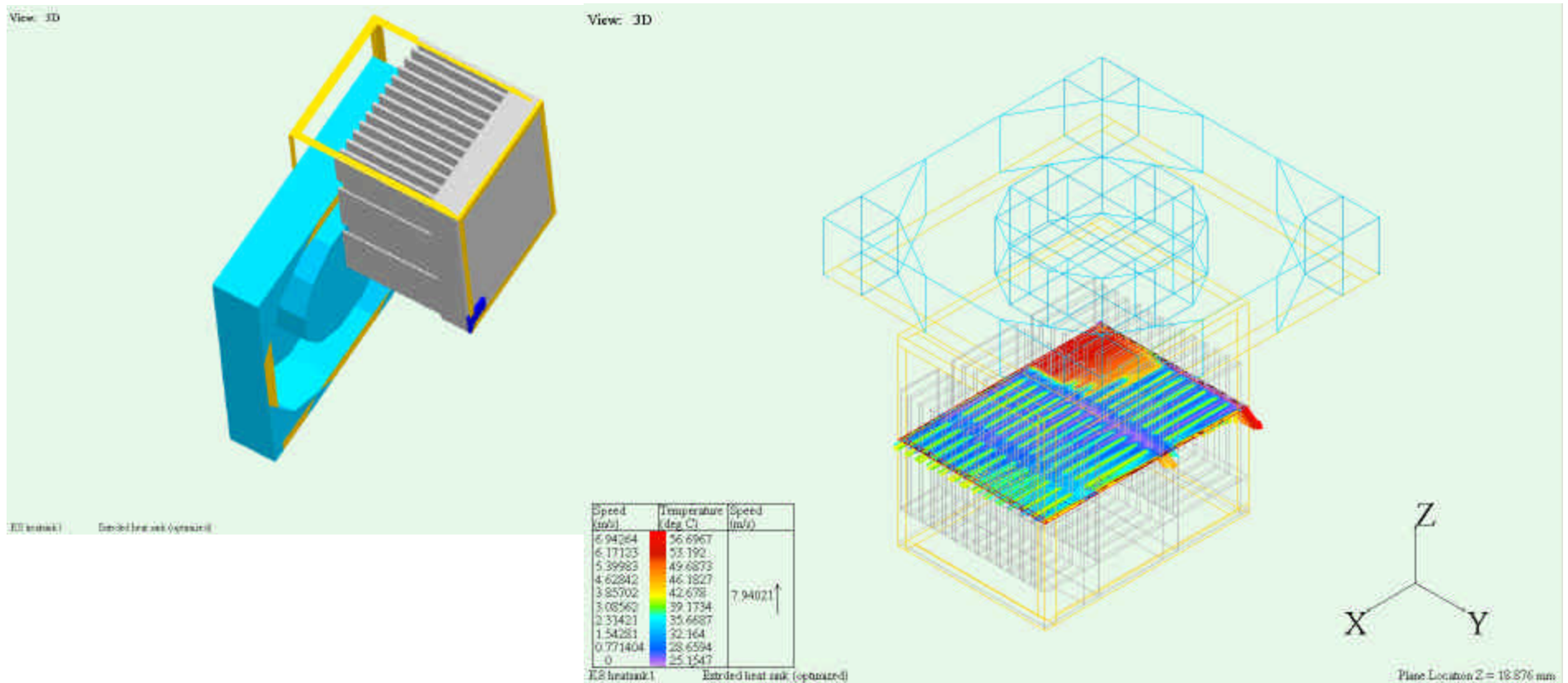


Engineering Analysis using Correlations



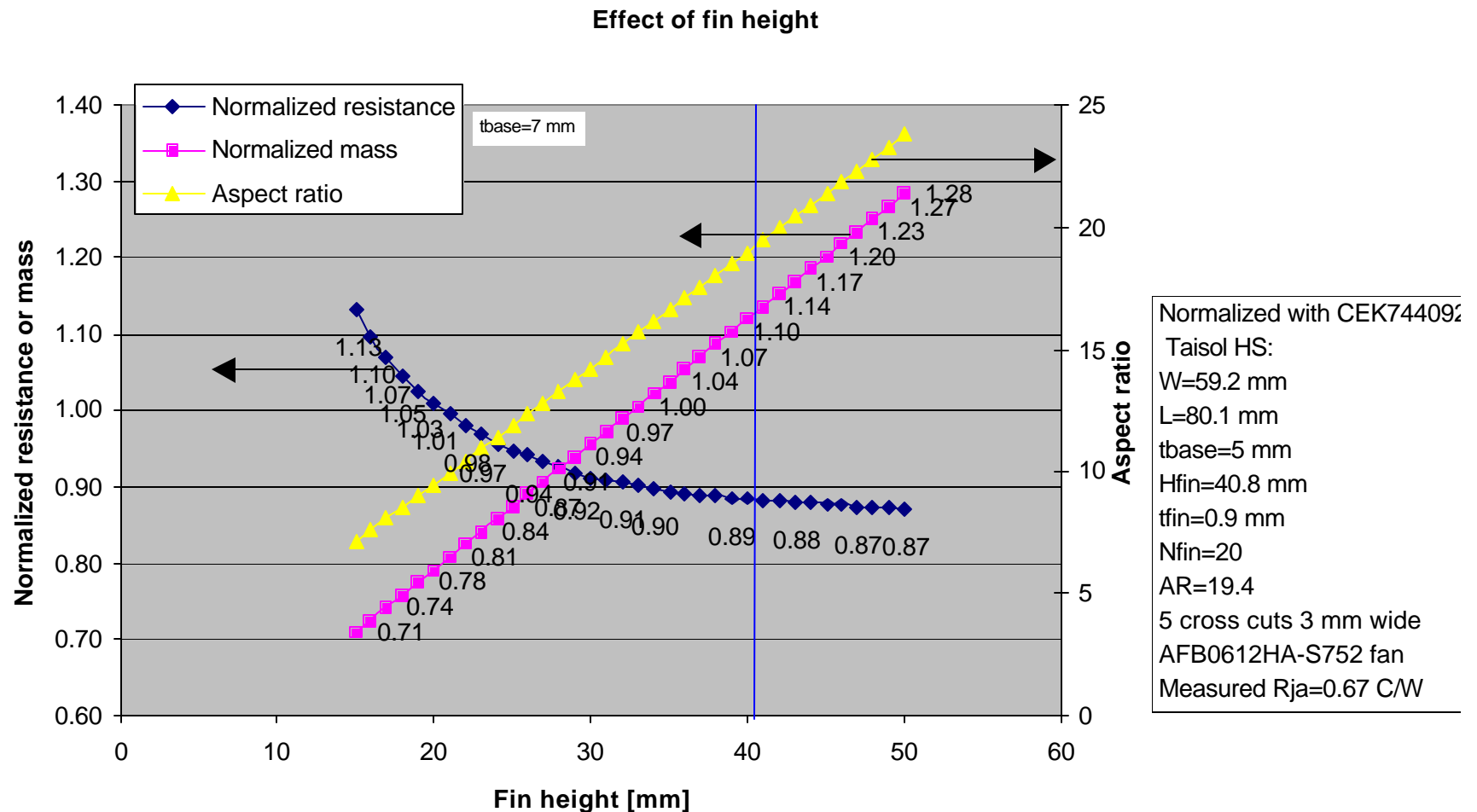


Flotherm 3-D One Quarter Model





Example Optimization





Heat Sink Attachment



Attachment Requirements

- **Stable, low thermal resistance connection between die and heat sink**
 - ✍ withstand temperature and power cycling without degrading
 - ✍ operational temperatures up to 95°C
- **Repeatable assembly to socket on motherboard**
 - ✍ performed manually while socket/processor is soldered to motherboard
 - ✍ insensitive to tolerances of the processor/heat sink assembly
- **Prevent rocking of the heat sink on the die surface**
 - ✍ prevent die-to-heat sink interface from separating after assembly
 - ✍ avoid chipping die during assembly
- **Withstand shock and vibration with up to 300 gm heat sink**
 - ✍ 50 g shock/11 ms pulse width; 6 drops/axis (3 +axis and 3 -axis)
 - ✍ random vibration 0.01g²/Hz @ 10 Hz; 0.02g²/Hz from 20 to 1K



AMD Athlon™ PGA Heat Sink Clips

- **Clip load requirements**

- ✍ Support pads provide max reaction load of 6 lbs
- ✍ Clip should deliver the following force:
 - » Min = 12 lbs
 - » Average = 16-18 lbs.
 - » Max load = 24 lbs

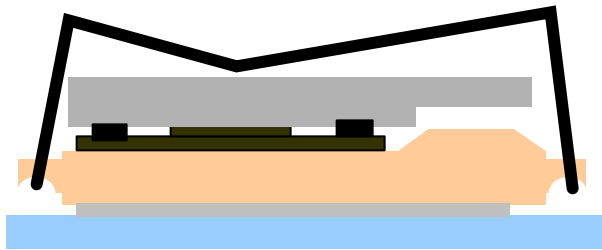
- **Single contact point clips should be used.**

- ✍ Clip load should be applied directly over die

- **A feature on the clip or heat sink should “lock” the relative position of the clip to the heat sink and socket.**

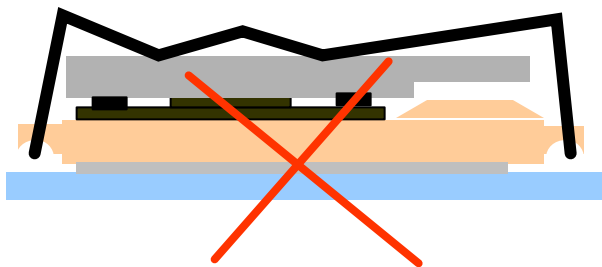
- **Clip should contain installation features to ease assembly.**

Heat Sink Clip Types



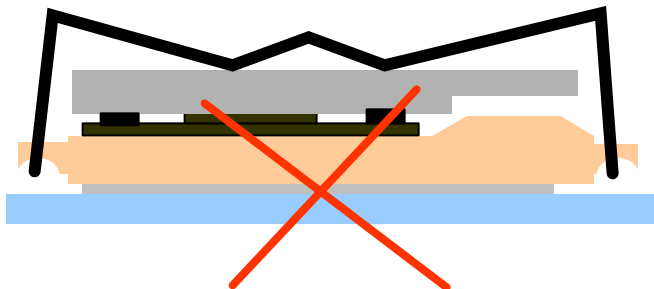
- **REQUIRED**

- ✍ Asymmetric single contact point
 - » Load applied at one point
 - --> no moment applied
 - » Pads stabilize attachment



- **NOT RECOMMENDED**

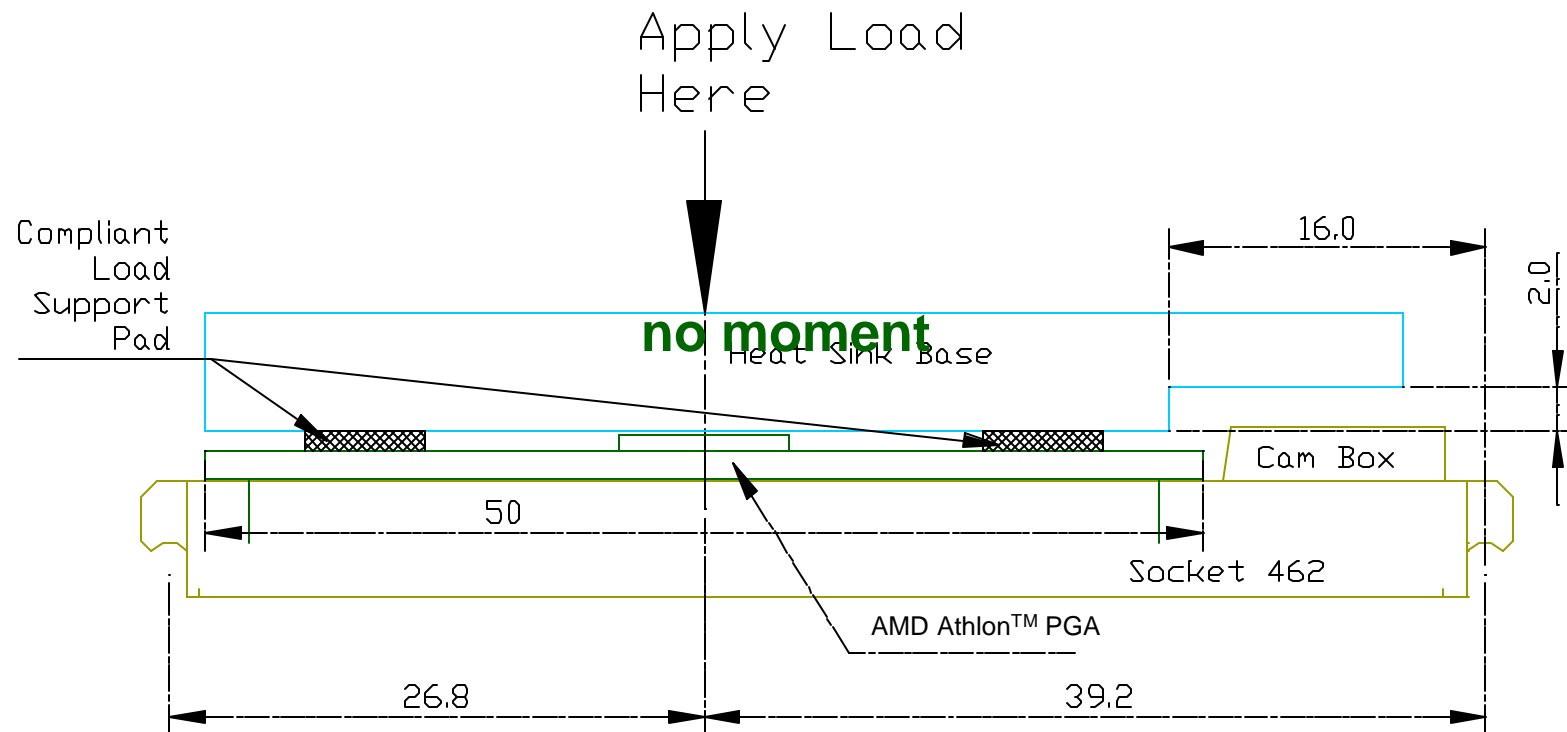
- ✍ Asymmetric, dual contact points
 - » loads applied by two points are not equal
 - » moment applied to attachment = rocking



- **NOT RECOMMENDED**

- ✍ Symmetric, dual contact points
 - » even if equal loads are not centered on die
 - » moment applied to attachment = rocking

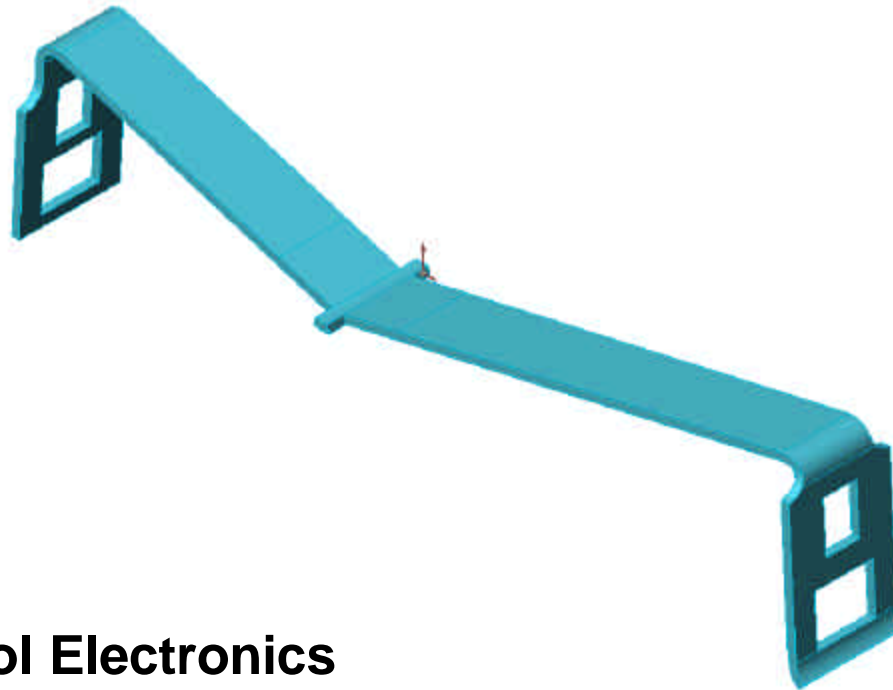
Drawing Detailing Clip Load Location



Heat sink fins are omitted for clarity.



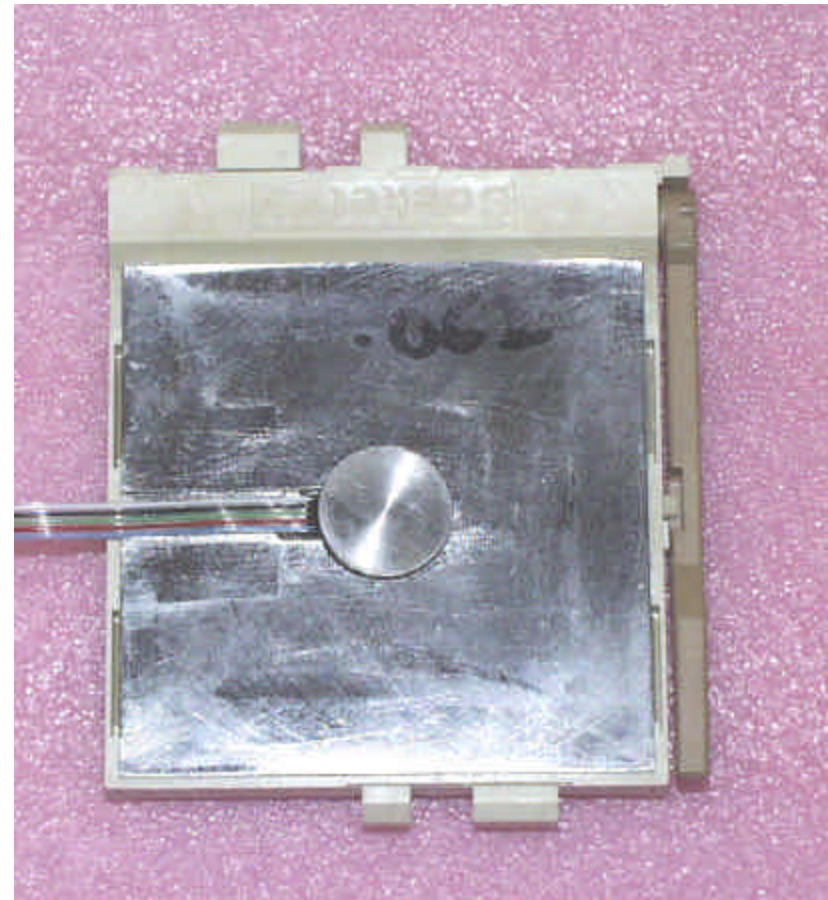
Example of Socket A Clip Design



Tai-Sol Electronics
DWG No. K7PGA006

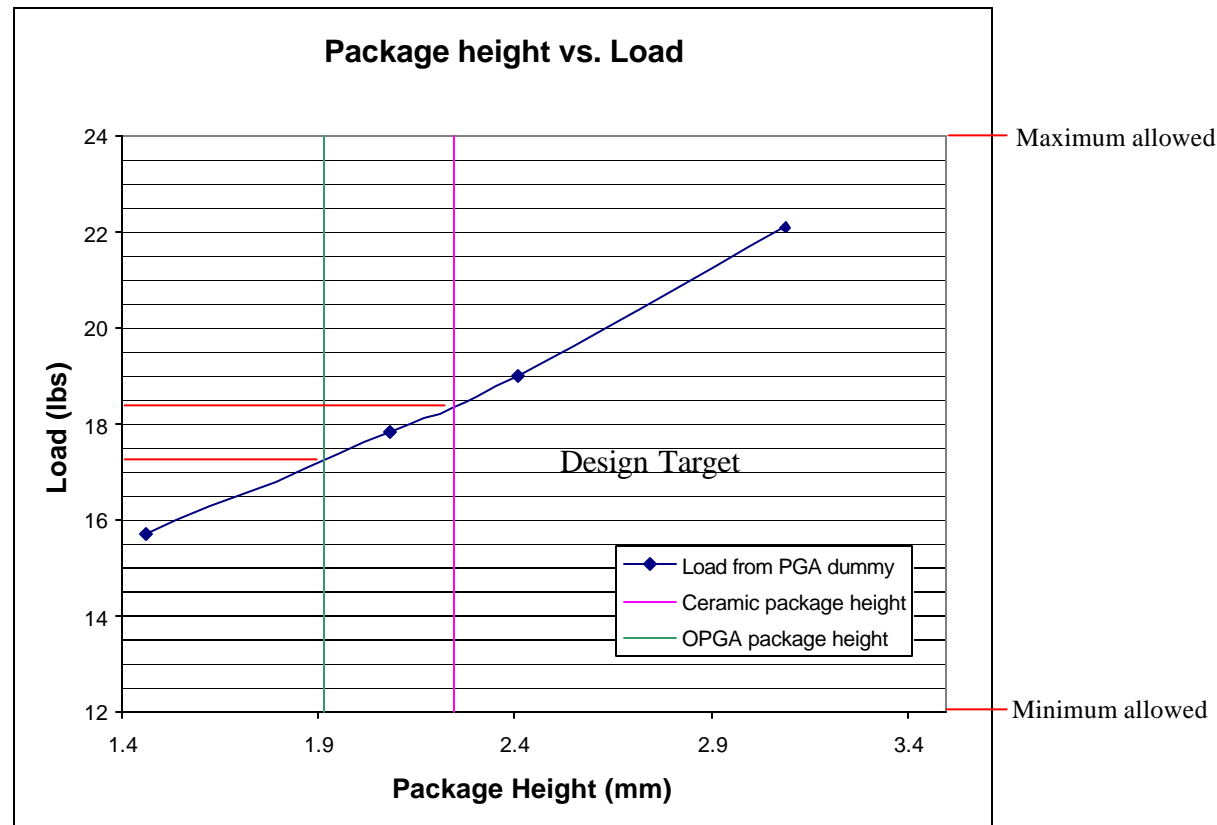
Load Cell Test Methodology

- Have steel package made at max, min and nominal material conditions
- Attach heat sink to load cell with and without compliant ring to determine load and load sharing





Clip Loads for OPGA and CPGA





Heat Sink Base and Interface Materials



AMD Athlon™ Processor Heat Sink Base Requirements



- **Heat sink base should contact all four pads.**
- **Heat sink base should clear cam box of socket.**
 - ✍ designs that extend over the cam box of the socket should clear this region to ensure that base cannot come to rest on socket for any heat sink base position.
- **Depth of cross cut slots for clips should be controlled.**
 - ✍ Cross cut depth impacts clip force.
 - ✍ Control to +/-0.25 mm to minimize impact on clip force.
- **Recommend a “non-anodized,” degreased heat sink finish**



Example Thermal Interface Materials for AMD Athlon™ PGA



- Chomerics
- Bergquist
- Shinetsu
- Furon
- Power Devices
- Thermagon
- Honeywell



Example Thermal Interface Materials for AMD Athlon™ PGA



- **Chomerics**

 T725*

 T454*

 T443*

- **Furon**

 1055**

 2055**

- **Honeywell**

 PCM45**

 PCM45F*

*

Interface	Min	Mean	Max	Range
T725	0.15	0.21	0.26	0.11
PCM45	0.15	0.22	0.28	0.13
G750 grease	0.14	0.22	0.29	0.15
TC-330 grease	0.16	0.24	0.31	0.15
T725	0.19	0.25	0.32	0.14
PCM45F	0.26	0.37	0.43	0.17
T443	0.45	0.53	0.60	0.15

- Non-anodized heat sink
- Scaled to 101 sq mm area
- Centered clip load ~ 13 lbs

Thermal greases are not recommended due to pumpout concerns.

* Materials are resistant to pumpout in slot form factor.

** Materials under test for pumpout.



Impact of Heat Sink Finish

Finish	Theta JS (C/W)	Increase from Degreased
Degreased	0.27	0
Gold Chromate	0.33	22%
Gold Chromate	0.33	22%
Black Anodized	0.42	56%

- Chomerics T725 used as the interface
- Heat transfer area = 117 sq mm
- Centered clip load applied



Heat Sink Infrastructure Development



Heat Sink Infrastructure Development

- Focus on fan sink development
- AMD works with vendor partners to develop heat sink reference designs into products
- AMD will test vendor-generated designs
- Part numbers that meet AMD specification on website



Heat Sink Testing Process

- Check physical dimensions.
- Check clearance during installation of clip.
- Verify single point clip and measure load
- Verify that there is a locking mechanism on clip or that heat sink base is designed to prevent it from resting on CAM of socket.
- Perform thermal evaluation of heat sink using internal test vehicle
- “Speed grade” heat sink according to temperature budgets defined earlier
 - ✍ Place on web site if it meets certain quality requirements
 - ✍ Provide feedback on how to improve design if possible



8/31/00

Re: P/N: PK8001AED1652

Dear Foxconn,

AMD has finished evaluating the PGA thermal solution you submitted for testing with the AMD Athlon processor. If thermal testing was successfully completed, the performance rating of this solution is included below. These results will be posted on our web site once the listed required changes (if any) are addressed and new samples are resubmitted. If the thermal testing was not completed, testing will be performed once new samples incorporating the required changes are submitted. Also included are some notes and/or recommendations.

Total Mass (g)	Clip load (lb)	Length (mm)	Width (mm)	Height (mm)
175	13.0	60	60	39

Test Power (W)	Interface Material	θ_{JS} ($^{\circ}\text{C/W}$)	θ_{SA} ($^{\circ}\text{C/W}$)	θ_{JA} ($^{\circ}\text{C/W}$)	Power Capacity@ 42 $^{\circ}\text{C}$ $\theta_{TJ-CPU \text{ Ambient}}$ (W)	Power Capacity@ 52 $^{\circ}\text{C}$ $\theta_{TJ-CPU \text{ Ambient}}$ (W)
70	T725	0.29	0.57	0.86	46.5	55.8

Based on the above results, this product will be recommended by AMD for the following CPU speed grades, pending any required changes:

Processor/System Configuration	Supported Speed (MHz)										
	550	600	650	700	750	800	850	900	950	1000	1100
AMD Athlon : With System fan	X	X	X	X	X	X	X	X	X	X	X
AMD Athlon: No System fan	X	X	X	X	X	X	X
AMD Duron: No System fan	X	X	X	X	X	X	X

Required changes for approval:

Recommended changes for improved performance:



External Web Site

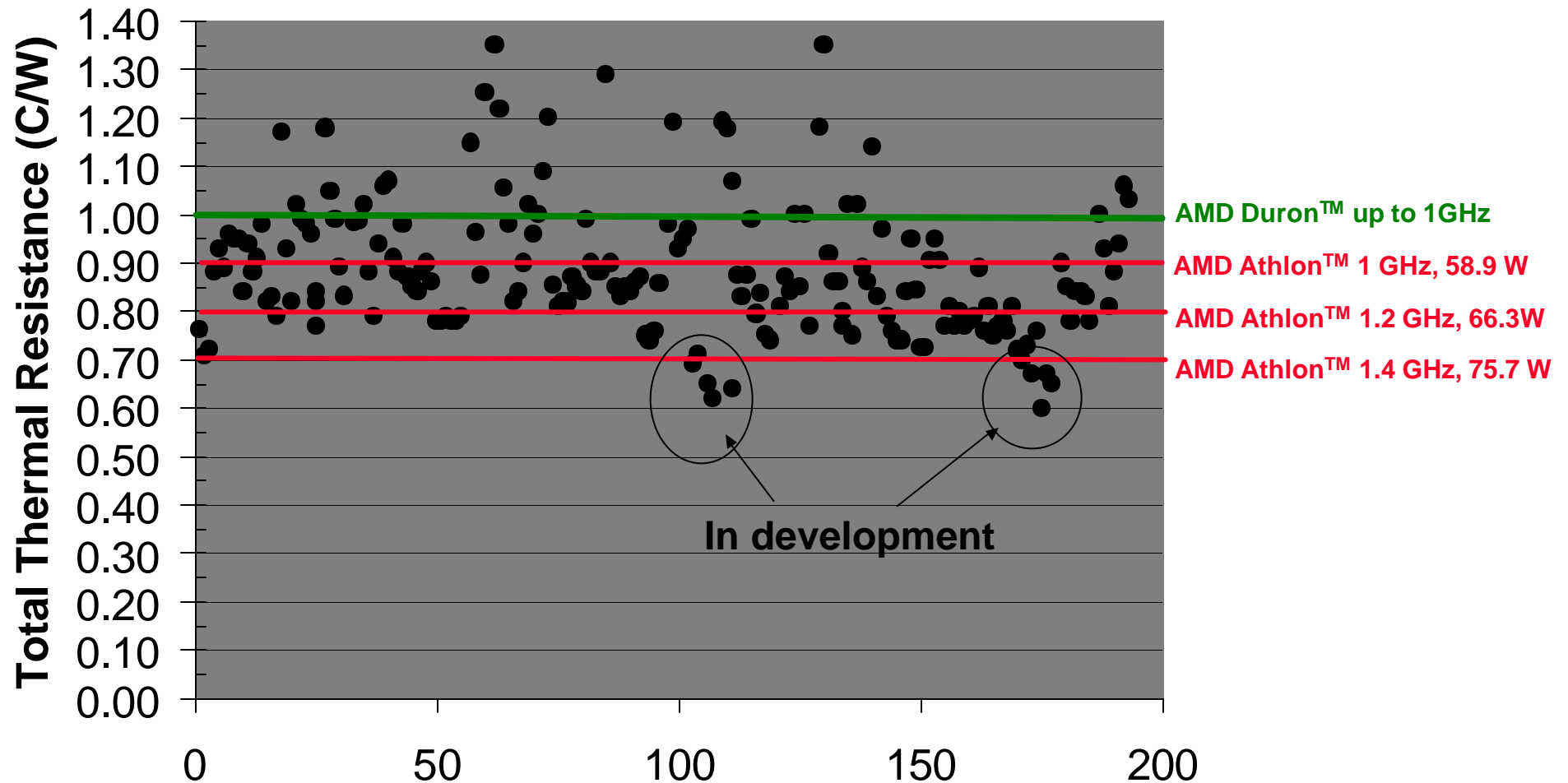
www1.amd.com/products/athlon/thermals

Manufacturer	Part Number	Form Factor	Recommended Processors (Click to View Notes)	Contact Information
Agilent	HACA-0001 (diameter = 64mm)	Socket	Athlon 950 Athlon 1000 Athlon 900 Athlon 850 Athlon 800 Athlon 750	View Contacts
Akasa	Icicle 630	Slot	Athlon 850 Athlon 800 Athlon 750 Athlon 700 Athlon 650 Athlon 600	View Contacts
Akasa	Icicle 650		Athlon 850 Athlon 800 Athlon 750 Athlon 700 Athlon 650 Athlon 600	View Contacts
Alpha	P 612 H35 M		Athlon 850 Athlon 800 Athlon 750 Athlon 700 Athlon 650 Athlon 600	View Contacts
Asian Vital Component (AVC)	112600CTH03	Socket	Athlon 950 Athlon 1000 Athlon 900 Athlon 850 Athlon 800 Athlon 750 Athlon 700 Athlon 650 Athlon 600	View Contacts
Asian Vital Component (AVC)	112600CTH04	Socket	Athlon 950 Athlon 1000 Athlon 900 Athlon 850 Athlon 800 Athlon 750 Athlon 700 Athlon 650 Athlon 600	View Contacts
			Athlon 850 Athlon 800 Athlon 750 Athlon 700 Athlon 650 Athlon 600	View

The screenshot shows a detailed thermal interface material (TIM) selection chart from the AMD website. The chart is organized into columns for Manufacturer, Part Number, Form Factor, Recommended Processors, and Contact Information. It lists various TIMs from manufacturers like Agilent, Akasa, Alpha, Asian Vital Component (AVC), and others. Each entry includes a link to view contact information. The chart is a comprehensive resource for selecting the right TIM for different AMD processors and form factors.



Summary of Heat Sink Database





1200 MHz Solutions

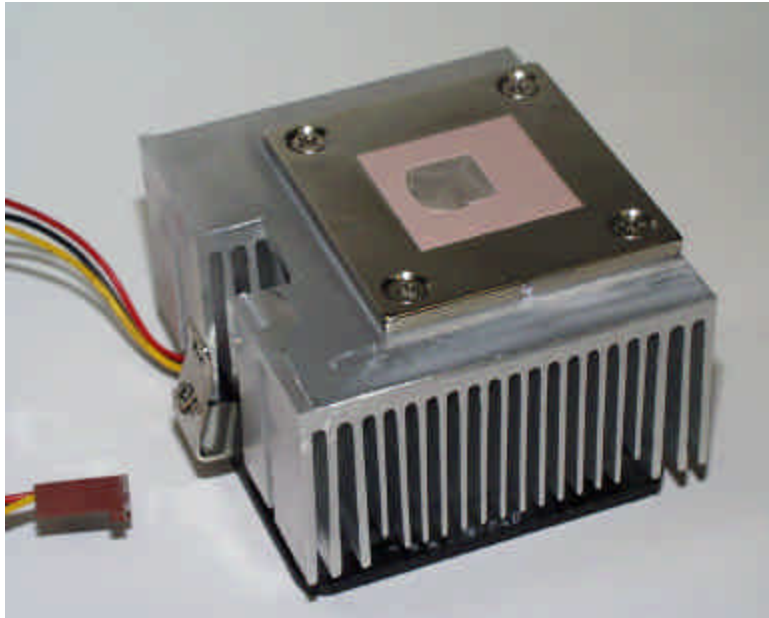


Vendor	P/N	Description	Weight	?ja
Foxconn	PK9921AEDBU52	60x80, 20 fin Al extrusion	221	0.75
Taisol	CEK733092	18 fin extrusion, 6mm Al base, 60 x60 heat sink base	158	0.79
TaiSol	CEK734092	18 fin extrusion, 6mm Al base, 60 x80 mm base		0.75
Agilent	HACA -0001	ArticCooler		0.72
Agilent	NL3	ArticCooler		0.71
Coolermaster	DP5-6H51-M1	19-Fin 60mm - Delta EFB0612HHA 60x15mm fan		0.79
CoolerMaster	DP5-6H11-A1	19-Fin 60mm - Delta EFB0612HHA dual ball fan		0.78
GlobalWin	FOP32-1	Extrusion 60mm, 60x25 fan, straight fins		0.75
JMC	FC4455CFX	17fin Single 60mm		0.77
PentAlpha	APSK0155-D	Non-Anodized 65x60mm base 19 fin heatsink #1		0.76
Tiger Electronics	SDA38000BC	60x80 mm, 19 fin Al extruded 3 tab, 2 bar non-SPC, with plate to guide flow.		0.78

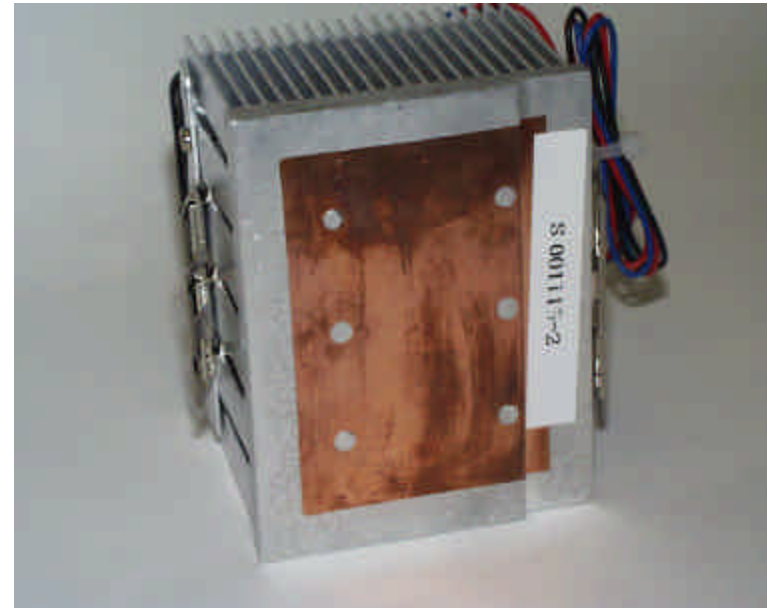
- All parts on external web site.

✍ All parts are aluminum extrusions

Heat Sinks Incorporating Copper



- **Foxconn PK0453AEDA52**
 - ✍ 63 x 70 x 60 mm
 - ✍ basic aluminum extrusion
 - ✍ 50 x 50 x 3mm Ni-plated Cu slug
 - » attached with four screws
 - » Shinetsu G751 grease



- **TaiSol S001115-2**
 - ✍ 60 x 80 x 60 mm
 - ✍ impact forged with copper insert
 - ✍ three bar clip with "Z" bar



Summary

- **Compliant load support pads and socket clip tabs provide stable, robust mechanical attachment**
- **Heat sinks designed and tooled for up to 1200 MHz**
✍ designs for 1300 MHz sampling
- **Designs for higher frequency products are in progress**
- **Specific thermal application notes written to provide information for customers**



Reference Documents



- **PID# 23792 AMD Athlon™ Processor PGA Datasheet (Rev. G, 1029/00)**
- **PID# 90020 AMD Athlon™ and AMD Duron™ Processor Socket 462 Design Guide (Rev. C, 8/1/00)**
- **PID# 24363 Motherboard PGA Design Guide (Rev. A, 10/11/00)**
- **PID# 90031 AMD Athlon™ Processor PGA Package Heat Sink Installation Application Note (Rev. C, 10/00)**
- **PID# 23828 AMD Athlon™ Processor EMC Design Application Note (Rev. A, 5/00)**
- **PID# 23794 AMD Thermal, Mechanical, and Chassis Cooling Design Guide (Rev. B, 10/00)**



Future requirements

- **AMD Athlon™ Processor**
 - ✍ Aluminum/copper hybrid heat sinks to reduce spreading resistance
 - ✍ Optimized high aspect ratio aluminum extrusions
 - ✍ Heat sinks using high density fin technology
 - ✍ Organic pin grid array package
- **Hammer family**
 - ✍ SMT uPGA socket
 - ✍ Chassis mounting